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MARKET POTENTIAL OF CLM IN CANADA

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1.0 INTRODUCTION (HISTORY OF CLM IN CANADA AND ABROAD)

CLM covers a number of fuels: coal-oil, coal-water and coal methanol are the ones most frequently heard about. Although laboratory scale experiments of CLM-combustion have been conducted by CANMET Fuel Research Laboratories during 1971, larger scale testing did not take place in Canada before 1977 when the NB Power Commission, with funds provided by the Federal Government, purchased an entire test equipment from GM and installed it in Chatham for tests on a 10 MW(e) Foster Wheeler boiler. At the same time, the Canadian Electrical Association (CEA) commissioned a study to establish the potential of COM in Canadian utilities, and to prepare the design for a large-size demonstration using a 100 MW(e) oil-fired boiler. The study, carried out by Monenco, showed that the conversion of the utility boilers in the maritime provinces could save some 5.25×10^6 barrels of oil annually. For reasons beyond the scope of this summary, this demonstration project never got beyond the drawing board. However, the drive towards large-scale utilization of COM continued at full speed in the United States; there are boilers up to 400 MW in Florida (Sanford Unit No. 4) today successfully operating with a mixture of 40-50% coal and oil.

The most serious competitor of coal-oil mixtures appears to be the coal-water mixture. Serious development work started just a few years ago in Sweden, but building partly on the experience gained with COM combustion, it appears to be already in commercial use in that country. Canada is getting close to embarking on the construction of its first large-scale (3 to 5 s.t/hr) CWM pilot plant, the product of which will be used in combustion tests at Chatham, to take place hopefully next year. Development work is also progressing in other countries, such as Japan, where an interruption in the oil

supply from abroad would have very serious consequences to the industry.

It is against this background that the International Energy Agency asked its member countries for contributions to an international study on the potential of coal-liquid mixtures. CANMET, as Canada's representative on the IEA, requested Monenco to conduct a country-wide survey on the potential for CLM; this presentation is intended to summarize the findings of that survey, the results of which were reported last July to the IEA.

2.0 HISTORY OF THE CLM SURVEY

The survey was conducted in three consecutive phases. Phase 1 was concerned with the Province of Nova Scotia, the largest Canadian user of imported fuel oil. The second phase covered the other maritime provinces, and the final phase dealt with the rest of Canada.

The method was basically the same throughout the study:

- We have obtained a list of the boilers and industrial process heaters that had a capacity over the limit stipulated in the Study Guidelines, i.e. 20 million BTU/hr heat input in the Maritimes and 50 million BTU/hr in all other provinces.

- A single page questionnaire was prepared and mailed to the owners of these boilers and heaters. Being aware of the dislike plant operators have to questionnaires, the questions

were strictly limited to those absolutely needed for the assessment.

- The questionnaires were followed by phone calls to the plant operators asking for clarifications or, in many cases, pleading with them to complete and return the questionnaires.

- The questionnaires were then interpreted and, where required, assumptions made in order to come up with expected oil consumption in the coming years.

- From the oil consumption, we then calculated the coal quantities required for two cases:

  - The quantities required if all boilers and heaters were converted to burn coal-oil mixture containing 50% coal and 50% oil by weight.

  - The required quantities if all the boilers and heaters were converted to coal-water mixture containing 75 to 80% coal and 20 to 25% water by weight.

Because of the unavoidable reduction of boiler capacity, for which we assumed various percentages, depending on whether the boiler was originally designed for oil or coal, there was always a shortfall in capacity after the conversion. This was accounted for by the hypothetical installation of new coal-fired boilers. The coal consumption of these new installations was added to the coal required in the mixtures in order to come up with a total coal demand.

It should be mentioned in passing that the list of boilers and heaters was not always easy to obtain, and it was even found necessary to ask the major heater manufacturers for a list of heaters

supplied to some provinces during the past 40 years. Nor was it easy to deal with some of the owners, and many thousands of dollars had to be spent on follow-up long distance phone calls.

3.0 SURVEY RESULTS

Turning now to the results of the survey, starting with the global picture.

FIGURE 1: OIL CONSUMPTION BY REGIONS

At the present time, the boilers and heaters surveyed consume approximately 38 x 10^6 barrels of fuel oil annually; 65% of this total is being consumed in the Maritimes, and Nova Scotia alone accounts for 8 x 10^6 bbl/yr, or 21% of the total. The distribution shown here is somewhat distorted by the discrepancy, stipulated in the study guidelines, between the heat input threshold in the Atlantic provinces (20 million BTU/hr) and in the rest of the country (50 million BTU/hr).

Putting into effect certain energy conservation measures, and substituting wood waste or other combustible by-products for oil, the 1984 consumption is forecast to 37.6 x 10^6 bbl/yr. This represents a drop of about 2% from 1981. The 1984 distribution is similar to that of 1981: 65% in the Maritimes and 20% in Nova Scotia.

FIGURE 2: OIL CONSUMPTION BY INDUSTRY

In this figure, a breakdown of the oil consumption by major industrial sectors is presented. Pulp and paper industry appears to be the heaviest user of oil by consuming more than half of the total

industrial oil consumption in Canada, or 12.2 million barrels/year. Obtaining information from refineries was the most difficult since most of them did not think burning CLM would be an attractive proposition. The section marked "others" include boilers used by universities, hospitals, auto manufacturers, tire manufacturers, etc.

FIGURE 3: OIL CONSUMPTION BY BOILER/HEATER TYPE

This figure presents a breakdown of the oil consumption by boiler or unit type. This breakdown was based on the original design of the boilers. In case of utility boilers, two major categories and four boiler types were considered:

- Originally designed for coal firing
- Originally designed for oil firing
  - Future coal capable
  - Compact design
  - Liberal design.

No boilers of future coal capable type were found. All oil-fired utility boilers are located in the Atlantic provinces.

On the industrial side, two major categories and four boiler types were considered:

- Originally designed for coal-firing

- Originally designed for oil-firing

  - Fire-tube

  - Water-tube

  - Field erected.

A large number of dual fuel boilers were also identified. These used oil as a backup or as supplementary fuel. In cases where the oil contribution in the production of steam was more than 30%, the boiler was considered as being oil-fired and then categorized according to its original design.

For industrial heaters/combustors, the same two major categories of oil and coal-firing were considered.

FIGURE 4: OIL-FIRED BOILERS AND HEATERS IN WESTERN CANADA

FIGURE 5: OIL-FIRED BOILERS AND HEATERS IN ONTARIO AND QUEBEC

FIGURE 6: OIL-FIRED BOILERS AND HEATERS IN THE ATLANTIC PROVINCES

The figures show the distribution of boilers and heaters covered in the survey. A total of about 300 units owned by 138 companies were identified. The maps indicate the location of companies irrespective of the number of units owned by them.

FIGURE 7: POTENTIAL OF OIL SAVINGS

This slide illustrates the estimated potential oil savings in Canada by conversion of all oil-fired units covered in this survey to COM or CWM.

The estimate is based on the following assumptions:

- Current average capacity factor of utility boilers: 50%
- Current average capacity factor of industrial boilers: 35%
- Current average capacity factor of heaters/combustors: 45%
- No efficiency loss due to conversion.
- No change in current capacity factors.

FIGURE 8: POTENTIAL OIL SAVINGS IN CANADA BY 1984

Figure 8 presents the quantity of oil that can be saved potentially by the use of CLM fuels in various regions of Canada, based on estimated consumption in 1984.

FIGURE 9: COAL ANALYSES

This shows the characteristics of coal obtained from the two mines.

4.0 COMPARISON OF COSTS AND BENEFITS FROM CONVERSION OF BOILERS IN UTILITIES AND IN INDUSTRY

In order to compare the economics of the conversion of utility boilers and industrial steam generators, we estimated the order-of-magnitude costs and savings for the conversion of boilers burning 1 million barrels of oil per year.

This is the amount of residual oil burned in the boiler of a 100 MW(e) steam-electric unit having an annual capacity factor of 0.71. The same amount will be consumed by 20 industrial boilers rated at 50 million BTU/hr heat input each, and having the same annual capacity factor of 0.71.

For both cases it was assumed that the CLM would be produced in a central preparation plant, and supplied to the user over an average distance of 160 Km.

The following two slides show the elements of the comparison: Figure 10 gives the investment and annual operating costs for the 100 MW(e) utility boiler, and Figure 11 for the 20 x 50 million BTU/hr industrial boilers.

FIGURE 10: CLM CONVERSION OF A 100 MW(e) UTILITY BOILER

	Oil	COM(1)	CWM(2)
Capital cost of conversion x 10^6 $	-	6.5	9.0

(1) 50% coal by weight

(2) 80% coal be weight

Annual Costs

		Oil	COM	CWM
Carrying charge	x 10^6 $	-	1.2	1.6
Fuel cost (1)	x 10^6 $	30.0	25.9	19.8
Fuel transport cost (2)	x 10^6 $	-	3.2	5.0
O and M cost (3)	x 10^6 $	-	0.3	0.4
Total	x 10^6 $	30.0	30.6	26.8
Savings Due to Conversion	x 10^6 $	-	-0.6	3.2

(1) Coal - $45/s.t., 12,500 Btu/lb
Oil - $30/bbl, 6.25 x 10^6 Btu/bbl
COM - $128.30/s.t., $17.00/s.t. preparation cost included, 15,500 Btu/lb
CWM - $63.20/s.t., $27.20/s.t. preparation cost included, 10,000 Btu/lb
Heat rate - 10,000 Btu/kWh
Annual capacity factor: 71%

(2) Fuel transport cost $16/s.t. for COM and CWM.

(3) O&M cost is 4% of capital cost.

FIGURE 11: CLM CONVERSION OF A 50 MILLION BTU/HR INDUSTRIAL BOILER

	Oil	COM	CWM
Capital cost of conversion x 10^3 $	-	505	700

Annual Costs

		Oil	COM	CWM
Carrying charge (18%)	x 10^3 $	-	91	126
Fuel cost (1)	x 10^3 $	1,500	1,293	988
Transport cost (2)	x 10^3 $	-	161	250
O and M cost (3)	x 10^3 $	-	20	28
Total	x 10^3 $	1,500	1,565	1,192
Savings Due to Conversion	x 10^3 $	-	-65	108

(1) Coal - $45/s.t., 12.500 Btu/lb
Oil - $30/bbl, 6.25 x 10^6 Btu/bbl
COM - $128.30/s.t., $17.00/s.t. preparation cost included, 15,500 Btu/lb
CWM - $63.20/s.t., $27.20/s.t. preparation cost included, 10,000 Btu/lb
Annual capacity factor - 0.71

(2) Fuel transport cost $16/s.t. for COM and CWM.

(3) O&M cost is 4% of capital cost.

As seen from the two slides, at the oil and coal prices assumed, there is a saving in converting to CWM, allowing the investment of a utility to be paid back in less than three years, and that of an industrial boiler in 6-1/2 years. The conversion to COM, however, would be uneconomical at the given fuel prices.

It should be pointed out that these results greatly depend on the actual price of oil and coal. For example, a 20% escalation in the price of both oil and coal (oil to $36/bbl, coal to $54/s.t.), would result in the following payback periods:

Payback period (years) for conversion to:	COM	CWM
Utility boiler	9	1-1/2
Industrial boiler	11	2

The sensitivity of the economics to fuel prices is illustrated on Figure 12.

It must also be pointed out that the above comparison is based on order-of-magnitude estimates, and the results should be viewed as an indication of a trend rather than budgetary figures. The trend appears to be positive for conversion to CWM, even at current fuel prices, and to both coal-liquid mixtures considered at increased oil prices, even if coal price should escalate proportionately to that of oil.

5.0 CONVERSION OF A CEMENT KILN FROM OIL TO COM

5.1 ASSUMPTIONS

While the kiln data on which the following estimates are based are realistic, the cement plant dealt with here is hypothetical.

It will be assumed that the plant consists of two long, dry kilns of the same size and capacity, both fuelled by oil.

Each kiln is 440 ft. (134m) long, and has a diameter of 10 to 11 ft. (3 to 3.4m).

Capacity of each kiln shall be 28.9 s.t/hr (26.25 to/hr) at max. cont. rating. With an annual utilization factor of 0.87, this represents an annual production of 200,000 to for one kiln, or 441,000 s.t/yr for the plant.

The theoretical heat input of a cement kiln is approximately 1,412,000 Btu/s.t (1,642 MJ/to) of product. However, the actual fuel heat input required, including losses of dry gas, shell radiation losses, and losses by uncondensed water vapour, amount to approximately 3,267,000 Btu/s.t (3,800 MJ/to) of cement produced in a kiln having a good efficiency. (All figures refer to the net calorific value of the fuel.)

If the plant would be using only residual fuel oil, the annual fuel consumption would be around 41,000 s.t. If the plant is converted to 50/50% coal-oil mixture firing, the annual COM burn rate is estimated at approx. 48,000 s.t.

5.2 THE PROCESS

Before trying to determine the costs and benefits that can be expected from the conversion of the cement plant to a coal-oil mixture, let us take a short look at the process itself.

The everyday cement plant uses some 80% of limestone and 20% of clay or shale, with a sprinkling of iron. The limestone ($CaCO_3$) comes from quarries in large size shot rocks; the clay or the shale is extracted from pits. These raw materials must be reduced in size and

mixed thoroughly to provide a uniform feed for the kiln. The size reduction is effected in steps: first, in a primary crusher, bringing the rocks down to approximately 6 to 8 inch chunks, in a secondary crusher to some 3/4 inch pieces and finally, in a mill to 80% passing a 200 mesh (74 microns, or 0.074 mm). Between and after the size reduction stages, the components are mixed in so-called homogenizing piles (some 30 - 40,000 tons) and homogenizing silos, until they become a uniform pulverized mass, which will be fed into the kiln either as a powder by air, or in slurry form by a pump.

The kiln, which is shown in a much simplified schematic sketch in Figure 13, is a long, slender cylinder, revolving slowly around its axis. The speed varies with the different kiln types from 1 to 3 RPM, but the evolution of the cement kilns being outside the scope of this short presentation, we will not delve into the reasons for this difference. The kilns we are describing here are of the long dry type, receiving the feed in powderized form and turning at a speed of 1.5 RPM.

The mix flows down the kiln, in counterflow to the combustion gases. It first passes through the drying zone, where hanging chains may be installed to assist in the heat exchange, then the calcining zone, finally to the burning zone, from where the hard clinkers exit into the cooler, to be cooled by the air blown in by a series of fans. The cement now has gypsum added to it, conveyed to the clinker crusher and grinding mills, and transferred to silos to be filled into bags and railway cars (either in bags or in bulk) for transportation to storage or job site.

The average composition of the cement is as follows (Figure 14).

Approximate Average Composition of Cement

Calcium oxide	(CaO)	63 %
Silica	(SiO_2)	22 %
Alumina	(Al_2O_3)	7 %
Iron oxide	(Fe_2O_3)	3 %
Magnesium oxide	(MgO)	2.7%
Sulphuric oxide	(SO_3)	1.7%
Alkalies and others		balance

5.3 FUELS

The heat is provided by the fuel entering the kiln at the end opposite to that of the feed entry. For our purposes it is important that the kiln is largely insensitive to the type of fuel used: most kilns were designed for coal firing but, in the bygone days of inexpensive oil, have been adapted without difficulty to burn residual fuel oil. Today many Canadian kilns burn natural gas and oil, one kiln is even fired by rubber tires. In the United Kingdom, a cement company has been successful in introducing municipal waste as fuel, and tests have also been conducted with this fuel in the United States and in a cement plant in Ontario but to date the results have not been entirely satisfactory in this country.

What concerns us here is the technical feasibility of providing the heat by a coal-oil-mixture, and it can be stated that the burning of both coal and oil in cement kilns is long established practice; no technical difficulties are to be faced, provided the mixture is low in sulphur. Sulphur would indeed cause problems by forming SO_3 in the combustion and corroding the refractory in a relatively short time. Similarly, large amounts of water could cause

problems. For this reason, we are not extending this hypothetical investigation beyond the use of COM to coal-water-mixtures. Also, it will be assumed that the coal used in the COM went through a beneficiation process, which significantly reduced the initial sulphur content, if required, and reduced the ash, which might also have contaminents harmful to the quality of the product.

5.4 ELEMENTS OF CONVERSION

As mentioned before, both coal and oil are fully accepted as cement kiln fuels. No structural change or internal modification of the kiln will be required for the new fuel.

There will be need for a new burner, with piping, valves and controls; a COM receiving station; transfer piping and pumps, and storage tanks with agitators.

The lower heating value of the COM, consisting of 50% of residual oil and 50% coal (by weight) has been calculated as being 14,727 Btu/lb.

Since one kiln uses 3.267×10^6 Btu/s.t. (3,800 MJ/to) of product, corresponding to 94.5×10^6 Btu/hr (99,740 MJ/hr) at full load, the hourly COM consumption of the two kilns will be 6.42 s.t/hr.

COM will be supplied in 20 ton trucks to the plant. For a one week storage at full capacity, storage tanks holding a total of roughly 1,100 s.t (approximately 1,000 tonnes) will have to be constructed.

5.5 ECONOMICS OF CONVERSION

For an order-of-magnitude economic analysis, the following assumptions will be made.

- Remaining life of plant — 15 years
- Coal price — $45 per s.t
- Annual oil consumption (before conversion) — 41,284 s.t
- Annual COM consumption — 48,928 s.t

The next slide (Figure 15) shows the capital investment and annual costs of the conversion. As seen from the bottom line, the annual savings from substituting COM for oil is $140,000, resulting in a payback period of slightly more than four years.

FIGURE 15: CLM CONVERSION OF 95 x 10^6 BTU/HR CEMENT KILN

	Oil	COM
Capital cost of conversion x 10^3 $ (Two kiln installation)	-	600
Annual Costs		
Capital charge (@18% p.a.) x 10^3 $		108
Fuel cost x 10^3 $	7,332	6,277

		Oil	COM
Transport cost		-	783
O and M cost		-	24
Total	x 10^3 $	7,332	7,192
Savings Due to Conversion	x 10^3 $		140

Coal - $45/s.t., 12,500 Btu/lb
Oil - $30/bbl, 6.25 x 10^6 Btu/bbl
COM - $128.30/s.t., including $17.00/s.t. preparation cost

This result is encouraging; as a subsequent analysis showed, it is also sensitive to changes in fuel costs. The next slide (Figure 16) shows the picture:

- The annual saving of $140,000 is for an oil price of $30 per barrel and a coal price of $45.00 per short ton.

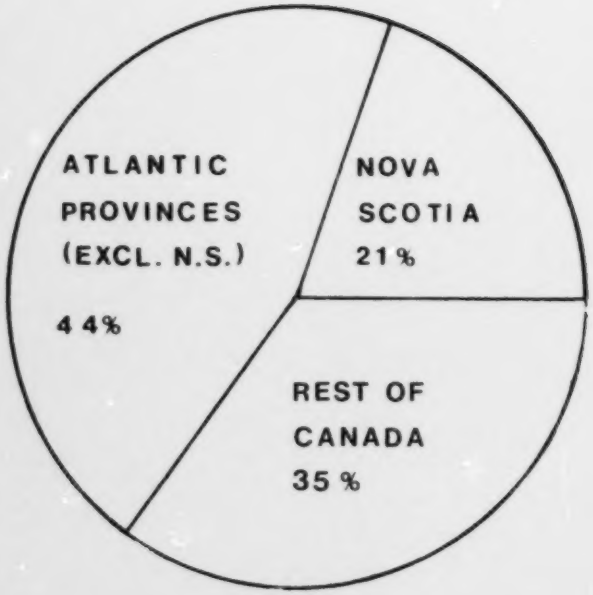
- If the coal price should increase to $50.00/s.t, the saving will be reduced to $17,000 p.a., and at a $55.00/s.t coal price, the saving will change to a loss of $105,000/yr.

- On the other hand, if the increase of the coal price to $55/s.t. were accompanied by an escalation of the oil price to $40/bbl, the annual saving would shoot up to $890,000/yr.

5.6 CONCLUSION

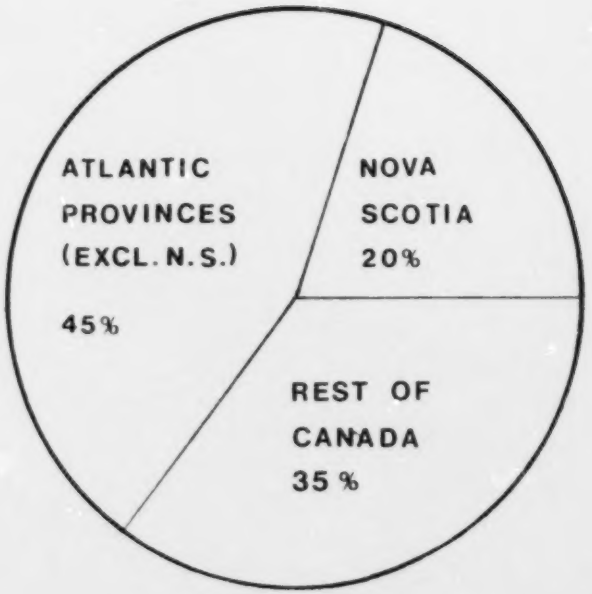
The conversion of a 2 kiln cement plant having an annual production of 400,000 tonnes to coal-oil mixture firing is technically feasible. Based on current levels of residual oil cost of $30/bbl and coal cost of $45/s.t, the conversion will result in an annual saving of $140,000 and will pay for itself within 51 months. Lower oil

prices as well as higher coal prices will tend to reduce the potential savings; higher oil prices will increase the savings even with proportional increases in the price of coal.



1980

TOTAL CONSUMPTION = 38 x 10^6 BBL

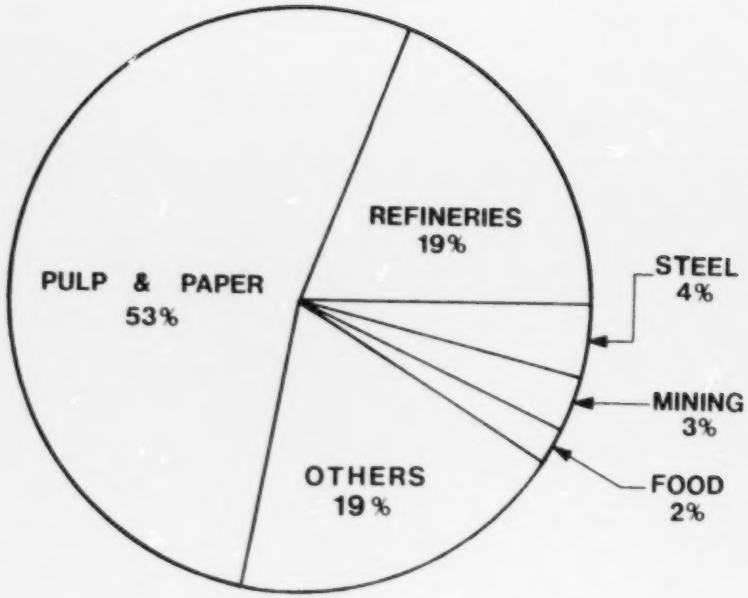


1984

ESTIMATED CONSUMPTION = 37.6 x 10^6 BBL

OIL CONSUMPTION BREAKDOWN BY REGIONS

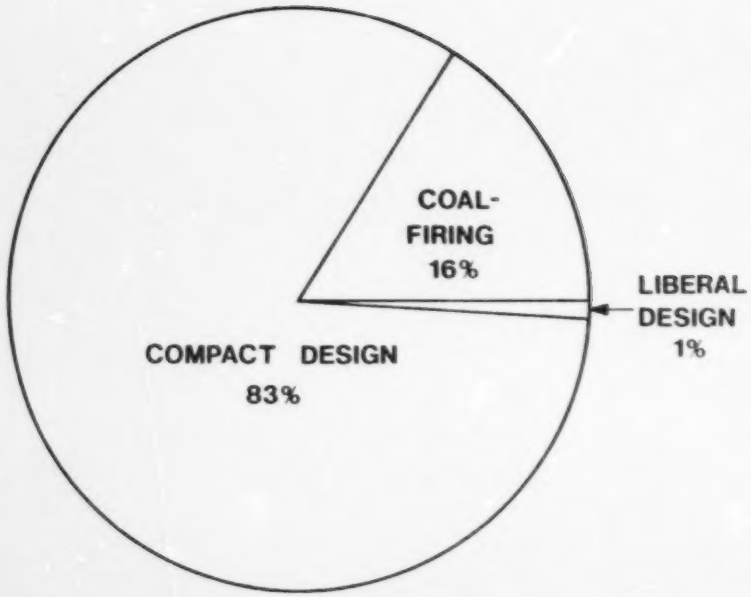
FIG.1



OIL CONSUMPTION BREAKDOWN BY INDUSTRY

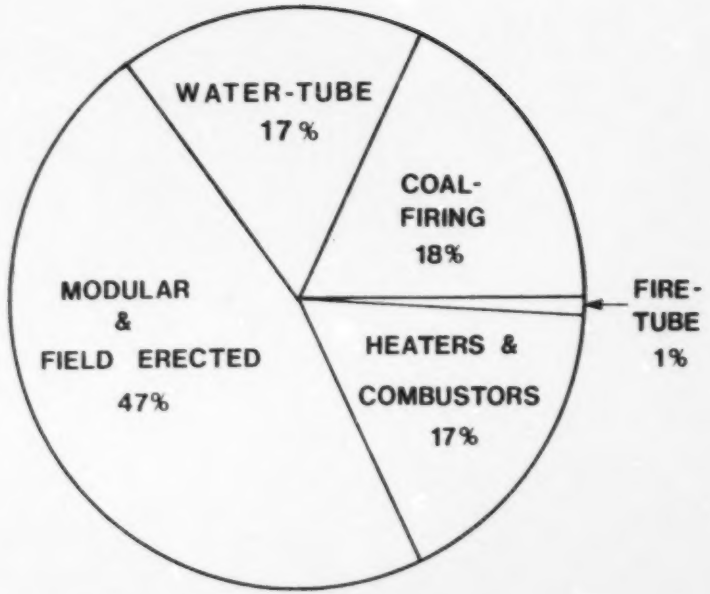
ESTIMATED TOTAL CONSUMPTION = 23 x 10^6 BBLs/yr

Fig. 2



UTILITY BOILERS

TOTAL CONSUMPTION = 15 x 10^6 BBL



INDUSTRIAL UNITS

TOTAL CONSUMPTION = 23 x 10^6 BBL

OIL CONSUMPTION BREAKDOWN BY BOILER/HEATER TYPE

Fig. 3

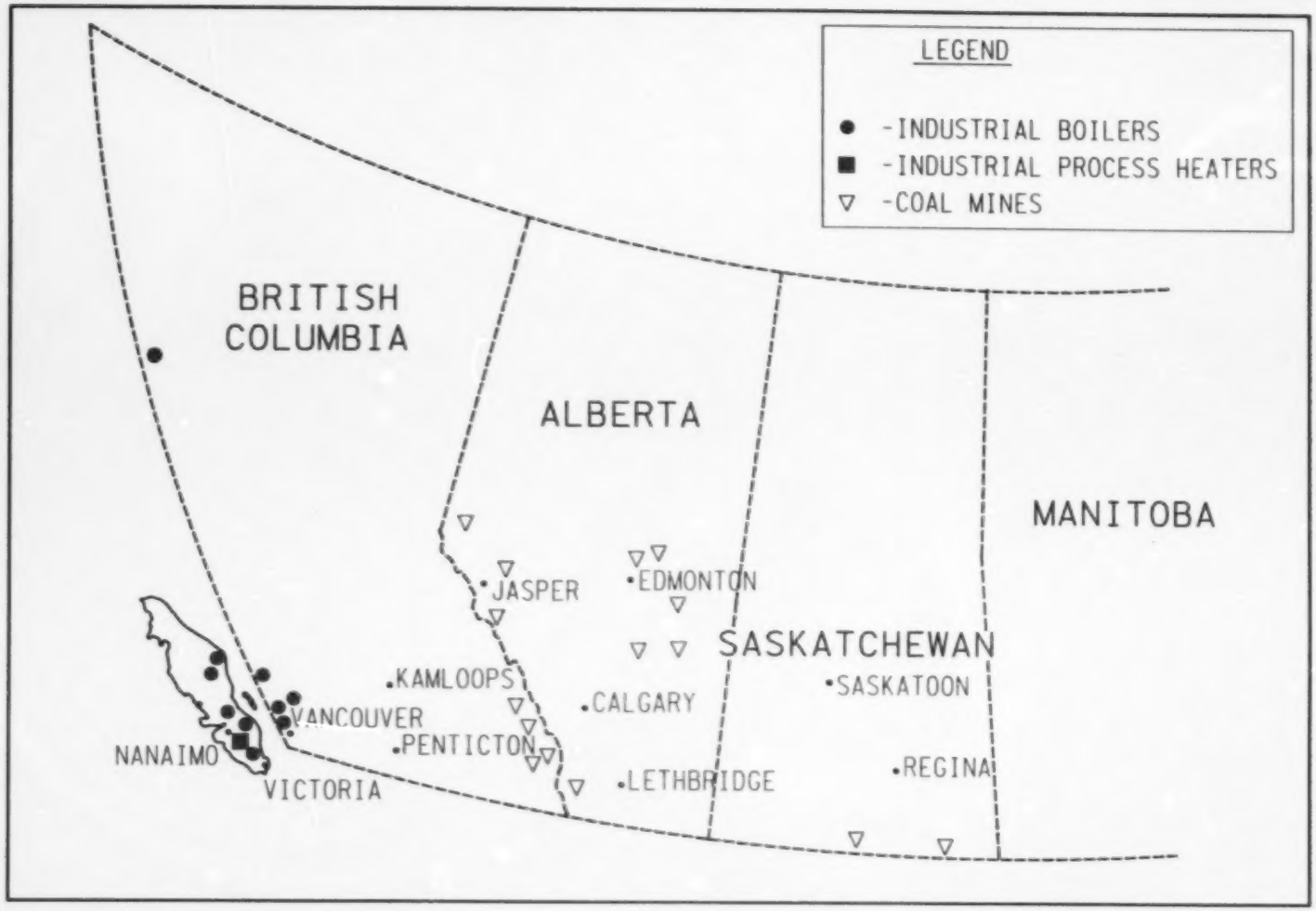


FIG. 4
DISTRIBUTION OF OIL FIRED BOILERS AND PROCESS HEATERS IN WESTERN CANADA

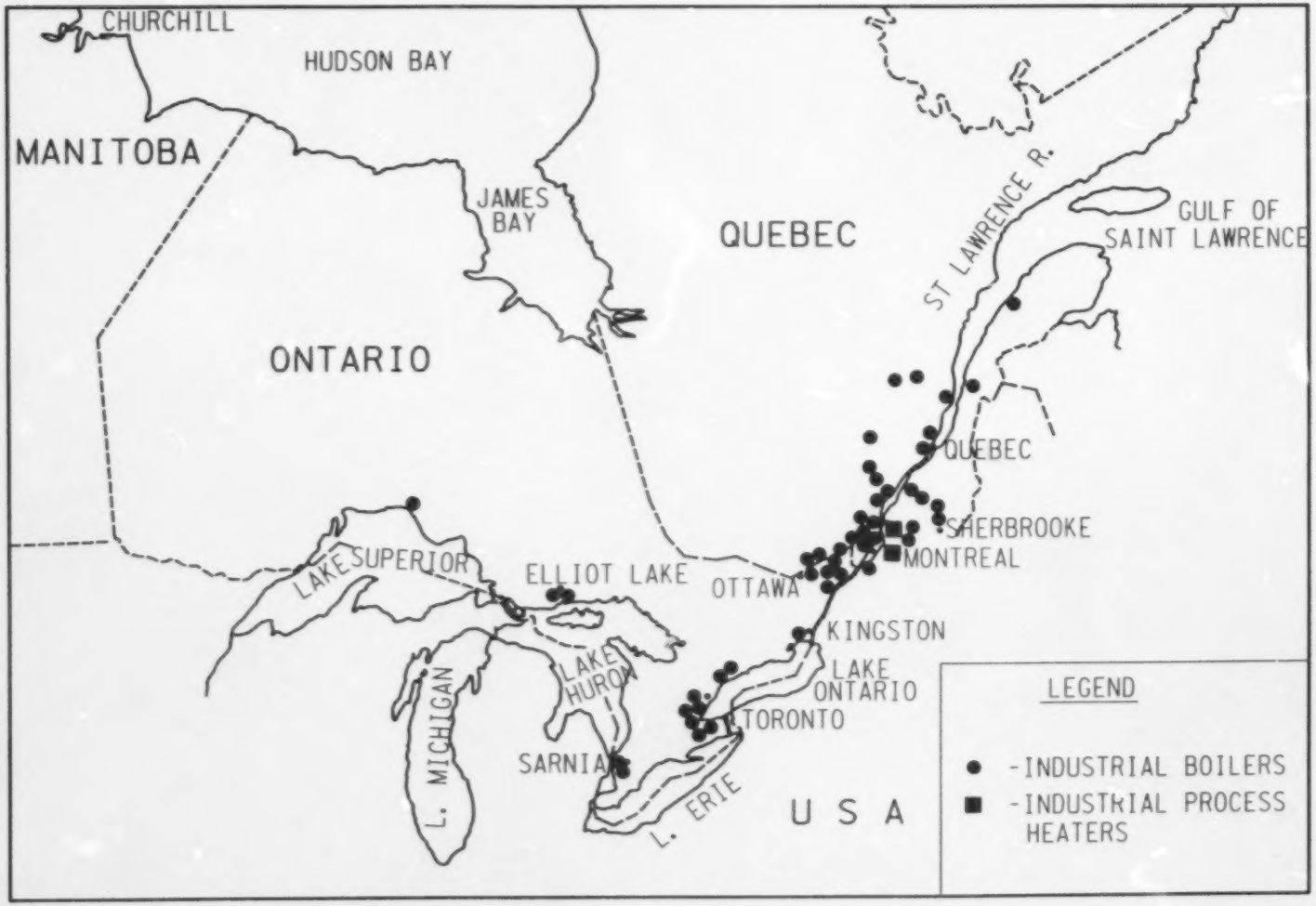


FIG. 5
DISTRIBUTION OF OIL FIRED BOILERS AND PROCESS HEATERS IN EASTERN CANADA

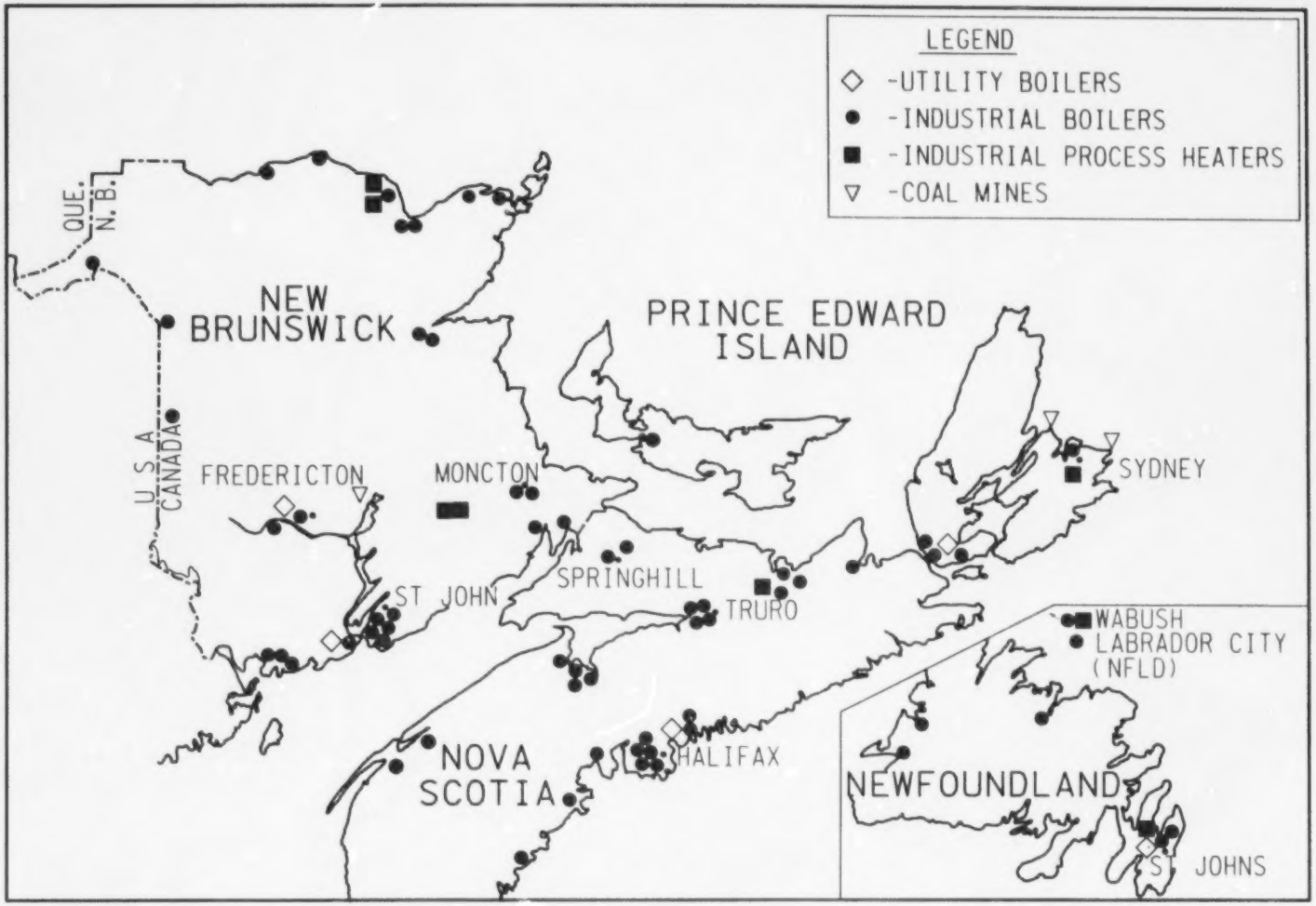
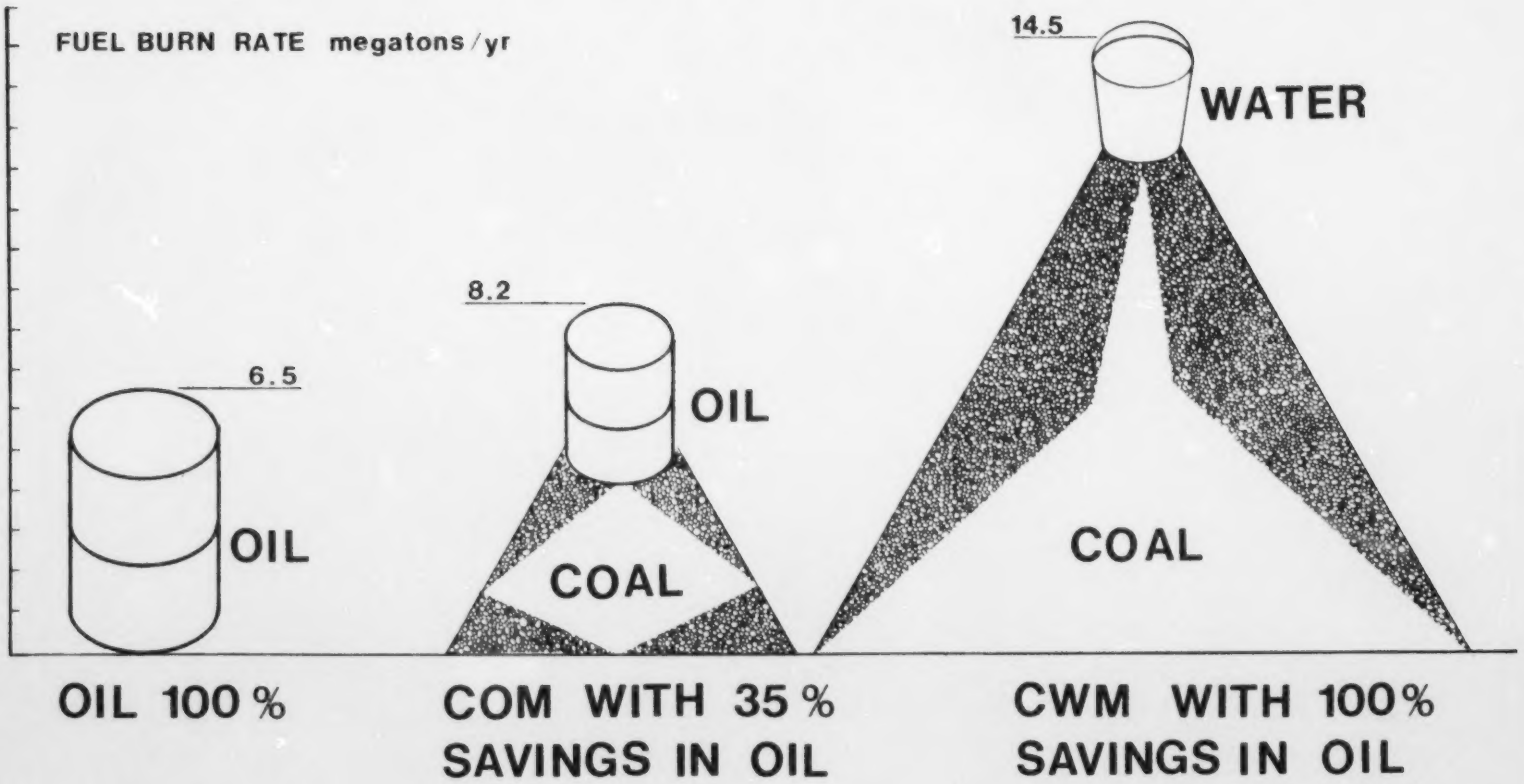
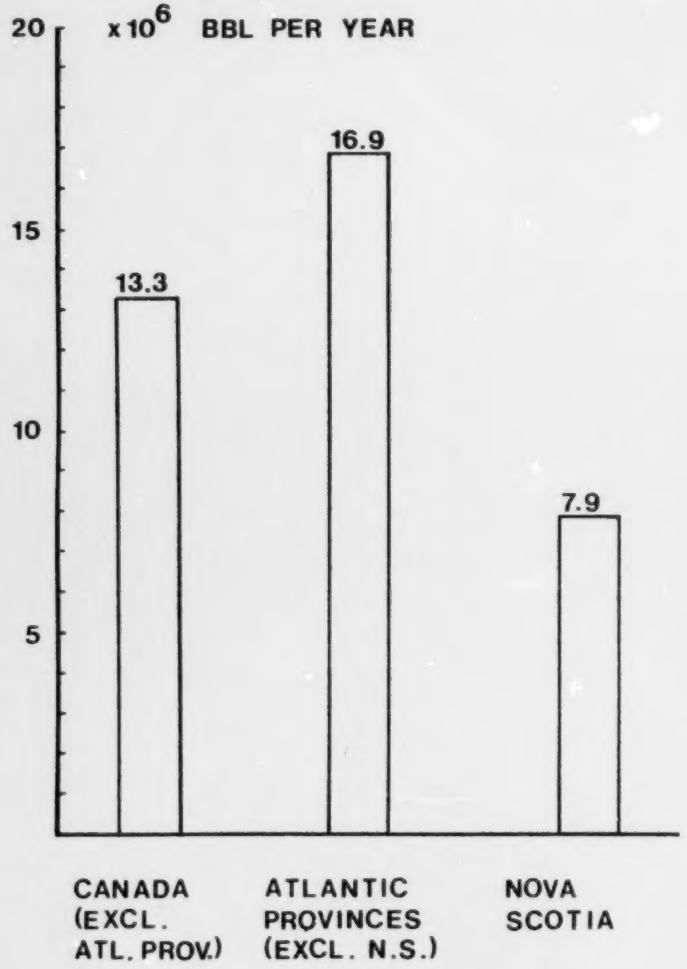


FIG. 6
DISTRIBUTION OF OIL FIRED BOILERS AND PROCESS HEATERS IN ATLANTIC PROVINCES

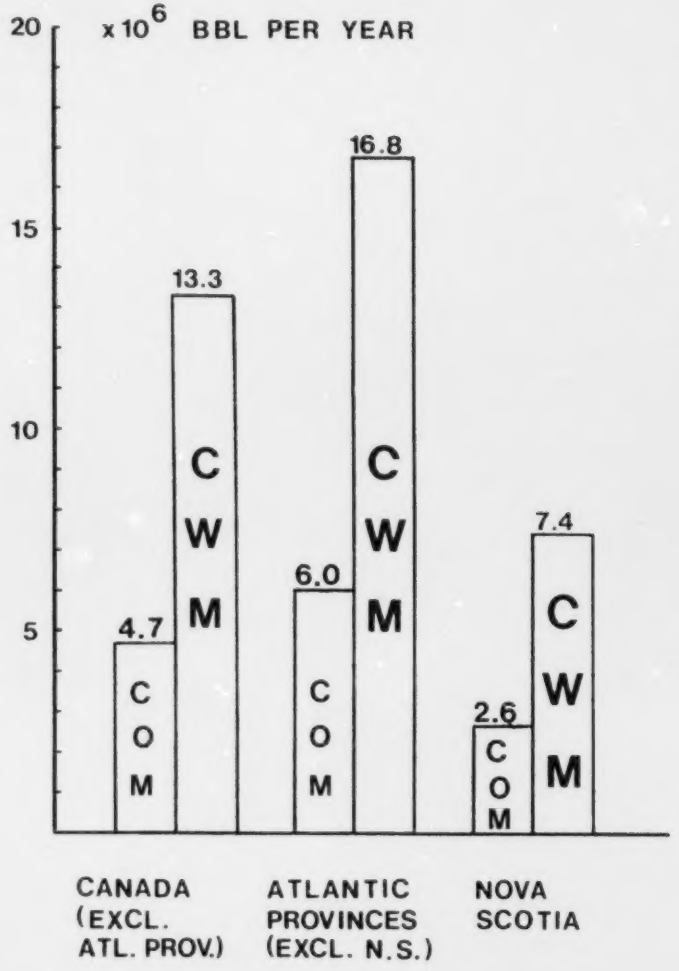


POTENTIAL OF OIL SAVINGS IN CANADA

FIG.7



CURRENT OIL USE
1980-1981



OIL SAVED BY
1984

FIG.8

COAL		NOVA SCOTIA SYDNEY AREA	ALBERTA FOOTHILLS REGION
H H V	BTU/lb	12,000	10,900
PROXIMATE ANALYSIS			
VOLATILES	(% BY WEIGHT)	30-32	34
FIXED CARBON		48-50	48
ASH		14-18	9
MOISTURE		6	9
ULTIMATE ANALYSIS			
CARBON	(% BY WEIGHT)	64-85	62
HYDROGEN		5.5	4.5
SULPHUR		2.6-4.5	0.8-1.0
OXYGEN		4.5-5.5	14.5
ASH		14-18	9
MOISTURE		6	9
GRINDABILITY HARDGROVE		65-70	44-55
ASH FUSION TEMP °F		2532	2196-2322
INORGANIC/ORGANIC SULPHUR RATIO		(87-136)/30	50/50
SUSCEPTIBILITY TO PHYSICAL BENEFICIATION			YES, TO SOME EXTENT

FIG. 9

		OIL	COM	CWM
CAPITAL COST OF CONVERSION	$\times 10^6$ $	—	6.5	9.0
ANNUAL COSTS				
CARRYING CHARGE		—	1.2	1.6
FUEL COST		30.0	25.9	19.8
FUEL TRANSPORT COST		—	3.2	5.0
O AND M COST		—	0.3	0.4
TOTAL		30.0	30.6	26.8
SAVINGS	$\times 10^6$ $	—	-0.6	3.2

CLM CONVERSION OF UTILITY BOILER-100MW

FIG.10

		OIL	COM	CWM
CAPITAL COST OF CONVERSION	x 10^6 $	–	10.1	14.0
ANNUAL COSTS				
CARRYING CHARGE		–	1.8	2.5
FUEL COST		30.0	25.9	19.8
TRANSPORT COST		–	3.2	5.0
O AND M COST		–	0.4	0.6
TOTAL	x 10^6 $	30.0	31.3	27.9
SAVINGS		–	-1.3	2.1

CLM CONVERSION -20x50 x 10^6BTU/HR INDUSTRIAL BOILERS

FIG.11

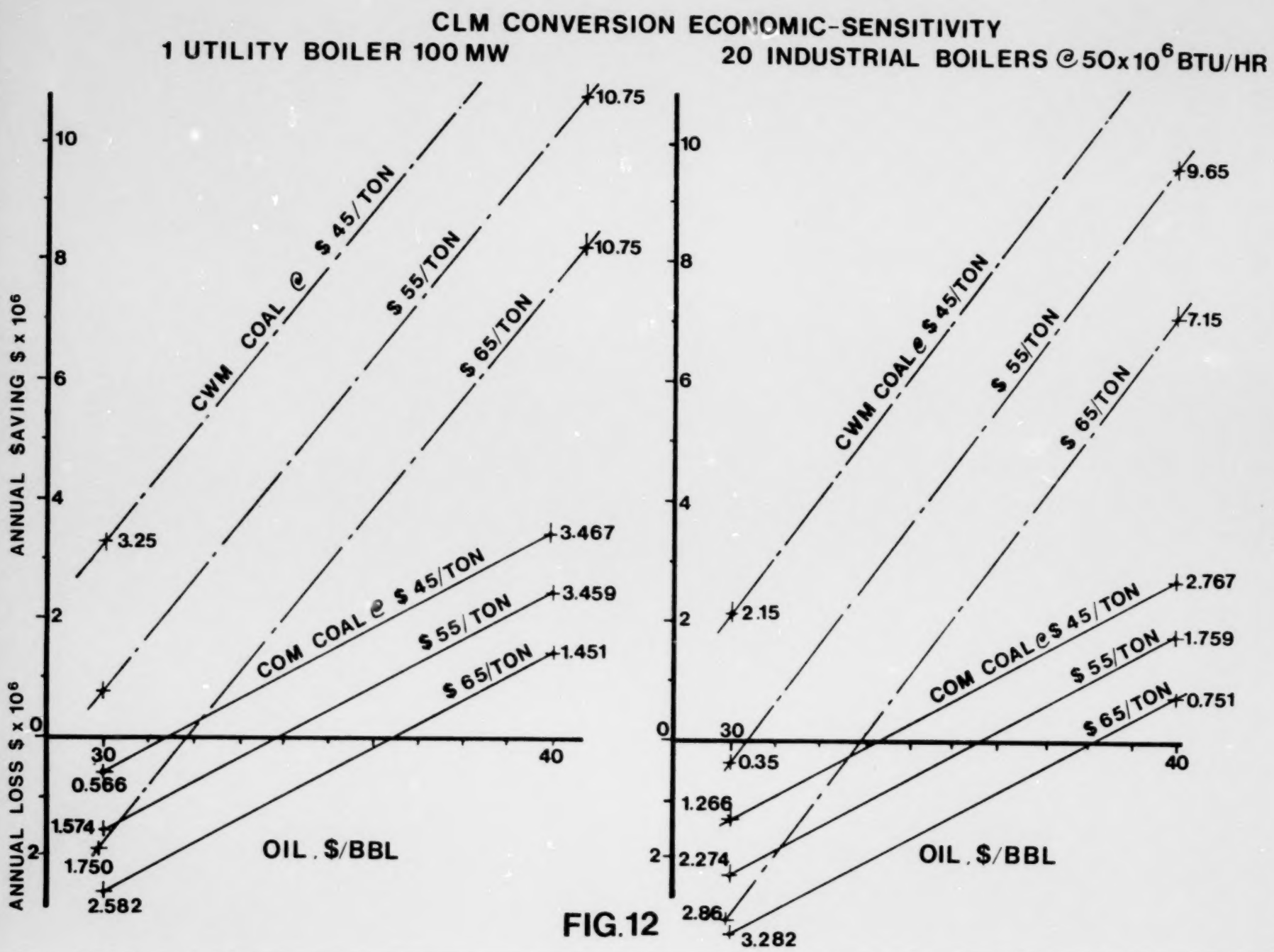
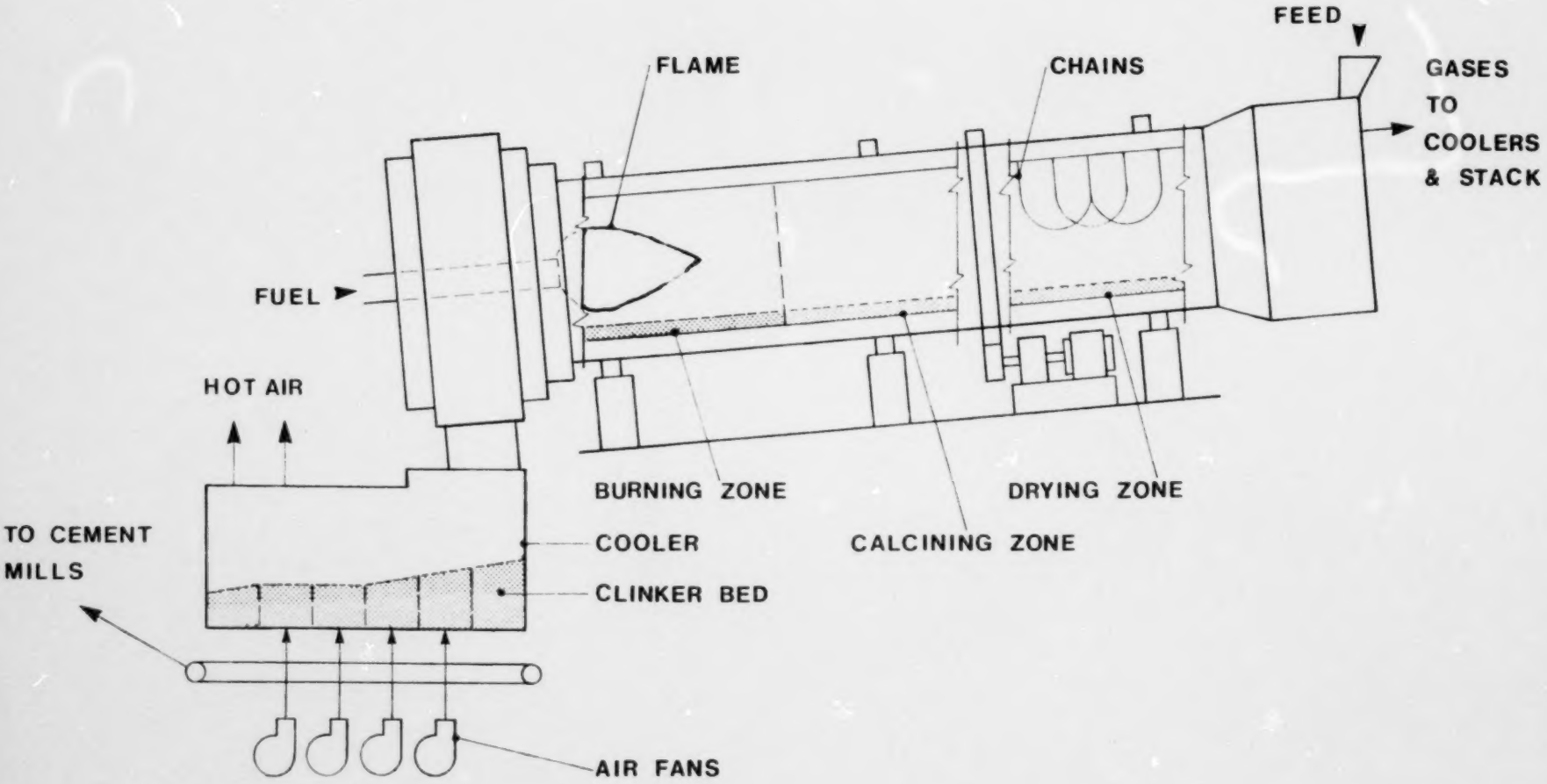

CLM CONVERSION ECONOMIC-SENSITIVITY
1 UTILITY BOILER 100 MW
20 INDUSTRIAL BOILERS @ 50x10^6 BTU/HR
ANNUAL SAVING $ x 10^6
ANNUAL LOSS $ x 10^6
CWM COAL @ $ 45/TON
$ 55/TON
$ 65/TON
COM COAL @ $ 45/TON
$ 55/TON
$ 65/TON
10.75
10.75
3.25
3.467
3.459
1.451
0.566
1.574
1.750
2.582
9.65
7.15
2.15
2.767
1.759
0.751
0.35
1.266
2.274
2.86
3.282
30
40
OIL . $/BBL

FIG.12



SCHEMATIC OF CEMENT KILN

FIG.13

APPROXIMATE AVERAGE COMPOSITION OF CEMENT

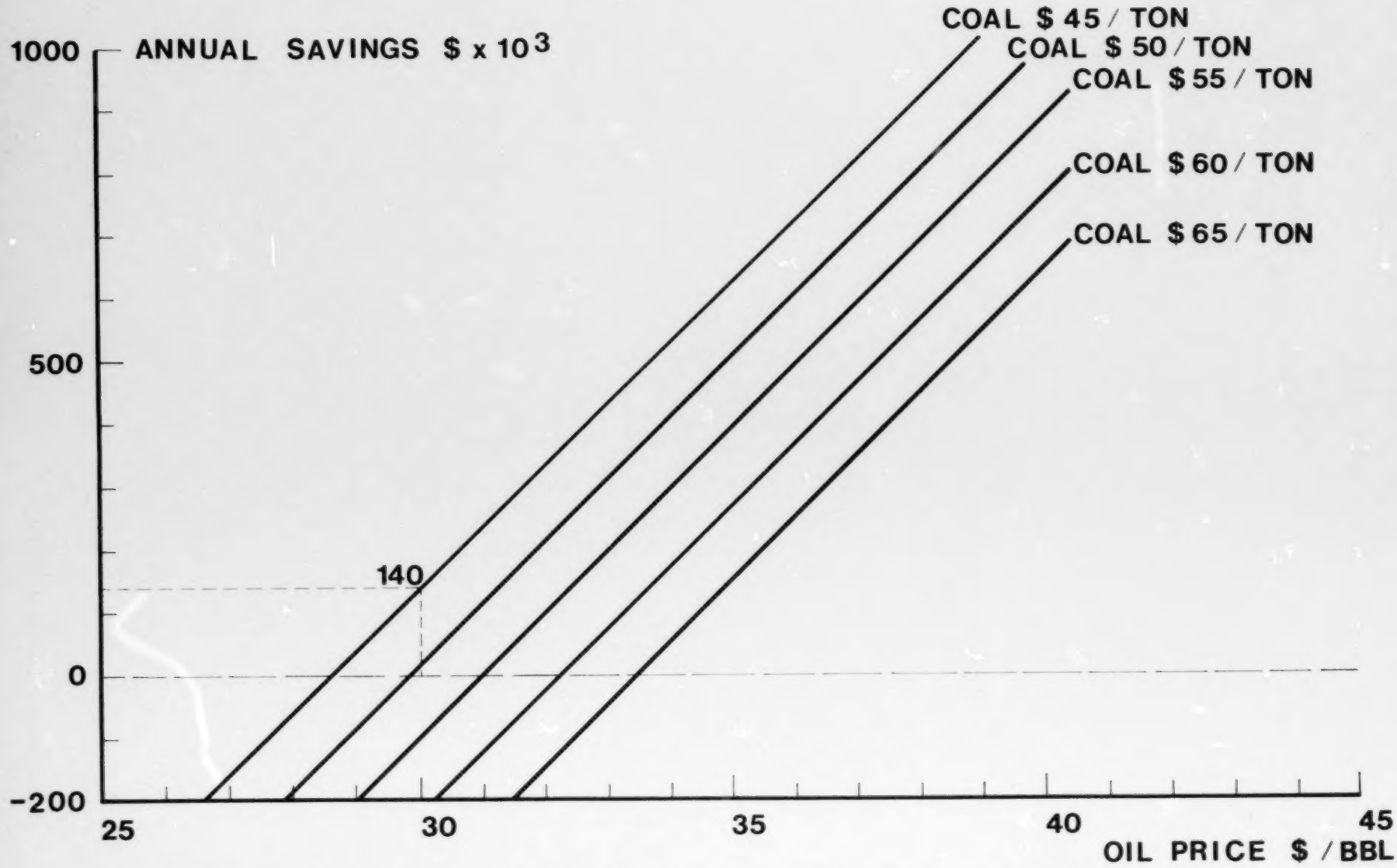
CALCIUM OXIDE	CaO	63%
SILICA	SiO_2	22%
ALUMINA	Al_2O_3	7%
IRON OXIDE	Fe_2O_3	3%
MAGNESIUM OXIDE	MgO	2.7%
SULPHURIC OXIDE	SO_3	1.7%
ALKALIES AND OTHERS		BALANCE

FIG.14

		OIL	COM
CAPITAL COST OF CONVERSION (TWO KILN INSTALLATION)	$\times 10^3$ $	–	600
ANNUAL COSTS			
CARRYING CHARGE		–	108
FUEL COST		7,332	6,277
FUEL TRANSPORT COST		–	783
O AND M COST		–	24
TOTAL		7,332	7,192
SAVINGS	$\times 10^3$ $	–	140

COM CONVERSION OF TWO 700 S.T./DAY CEMENT KILNS

FIG.15



CEMENT PLANT COM CONVERSION—SENSITIVITY ANALYSIS

FIG.16